H. Biteau, G. Marlair, D. Drysdale and J.L. Torero, *Characterisation of the Thermal and Chemical Effects of Energetic Materials not Likely to Detonate*, 31st International Symposium on Combustion, Work-in-Progress Poster, Heidelberg, Germany (2006) 197.

Characterisation Of The Thermal And Chemical Effects Of Energetic Materials Not Likely To Detonate

H. Biteau[1], G. Marlair[2], D. Drysdale[1] and J.L. Torero[1]

[1]**BRE Centre for Fire Safety Engineering,** The University of Edinburgh, UK;
[2]**Institut National de l'Environnement et des Risques Industriels**, INERIS, France;

Introduction

Energetic materials encompass a wide range of chemical compounds all associated with a significant risk of fire and explosion. They include explosives, pyrotechnic materials, powders, fertilizers and other unsteady chemicals. These materials store a high level of chemical energy and are able to release it rapidly without external contribution of oxygen or other oxidizer.
The aim of this work is the analysis of thermal and chemical characteristics of energy-rich materials under conditions that exclude detonations in order to better isolate the mechanisms involved in the burning process. The fire behaviour of energetic materials differs from that of classic solid fuels mainly due to the internal supply of oxidizer. This peculiarity precludes the use of established techniques as oxygen consumption calorimetry to study its fire performance.

Methodology

In order to develop a robust methodology to predict the Heat Release Rate during the decomposition of energetic material, the applicability of Oxygen Consumption Calorimetry [Babrauskas and Janssens] has been first evaluated. This procedure assumes several simplifications, which could lead to uncertainties in the results [Brohez]. A comparison of HRR measurement using different methods has been carried out for an energetic fuel (heptane) and a solid fuel (PMMA).
.

Experimental Work

The experimental work is being conducted using the FM Global Fire Propagation Apparatus FPA [ASTM E2058-03], also called Tewarson Calorimeter. One of the benefits of using this device rather than the Cone Calorimeter is that it allows controlling the feed of heat and oxidizer to the reaction zone.

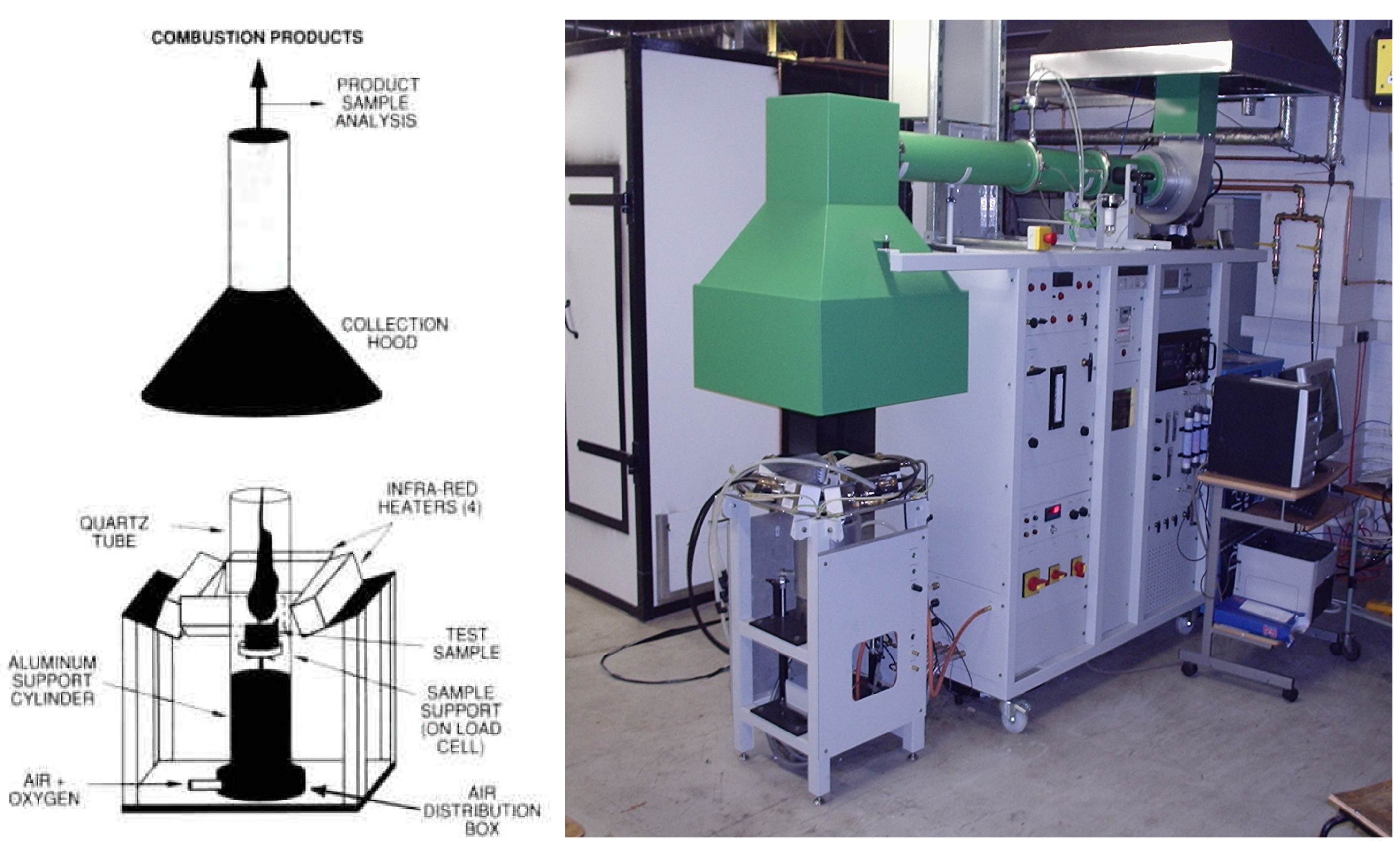

Figure. 1 : Schematic Diagram of The Fire Propagation Apparatus [ASTM E2058-03].

Results

The results have shown :

– In the case of well-ventilated combustion, the Heat Release Rate calculated by means of Oxygen Consumption Calorimetry differs between 8 and 15% from the HRR calculated by using the material's Heat of Combustion (Fig. 2.a, 2.b);

– In the case of under-ventilated combustion, the difference between the 2 procedures is more important (30% in average for the heptane test with an incoming flow of 60 l/min). The calculations include a correction for CO generation.

– These differences on the HRR measurement increase when average values for the energy released per unit mass of O_2 consumed, E and the expansion factor, α (a number of moles in the fraction of air fully depleted of its oxygen is replaced by a equal or larger number of moles of combustion products in the exhaust flow) are used.

Results (continued)

– The variation induced by using average value instead of actual value for E, the energy released per unit mass of O_2 consumed is between 1 and 5%.

– The variation induced by using an average value instead of actual values for the expansion factor α is between 1 and 2%.

When the chemical composition of the burning fuel is known, actual values for calorimetric coefficients should be used. The results found with Oxygen Consumption Calorimetry tend to be close to those found by means of the material's Heat of Combustion for well-ventilated fires. For under-ventilated combustion, corrections have been applied in the calculations for CO generation. Discrepancies increase compared to well-ventilated combustion.

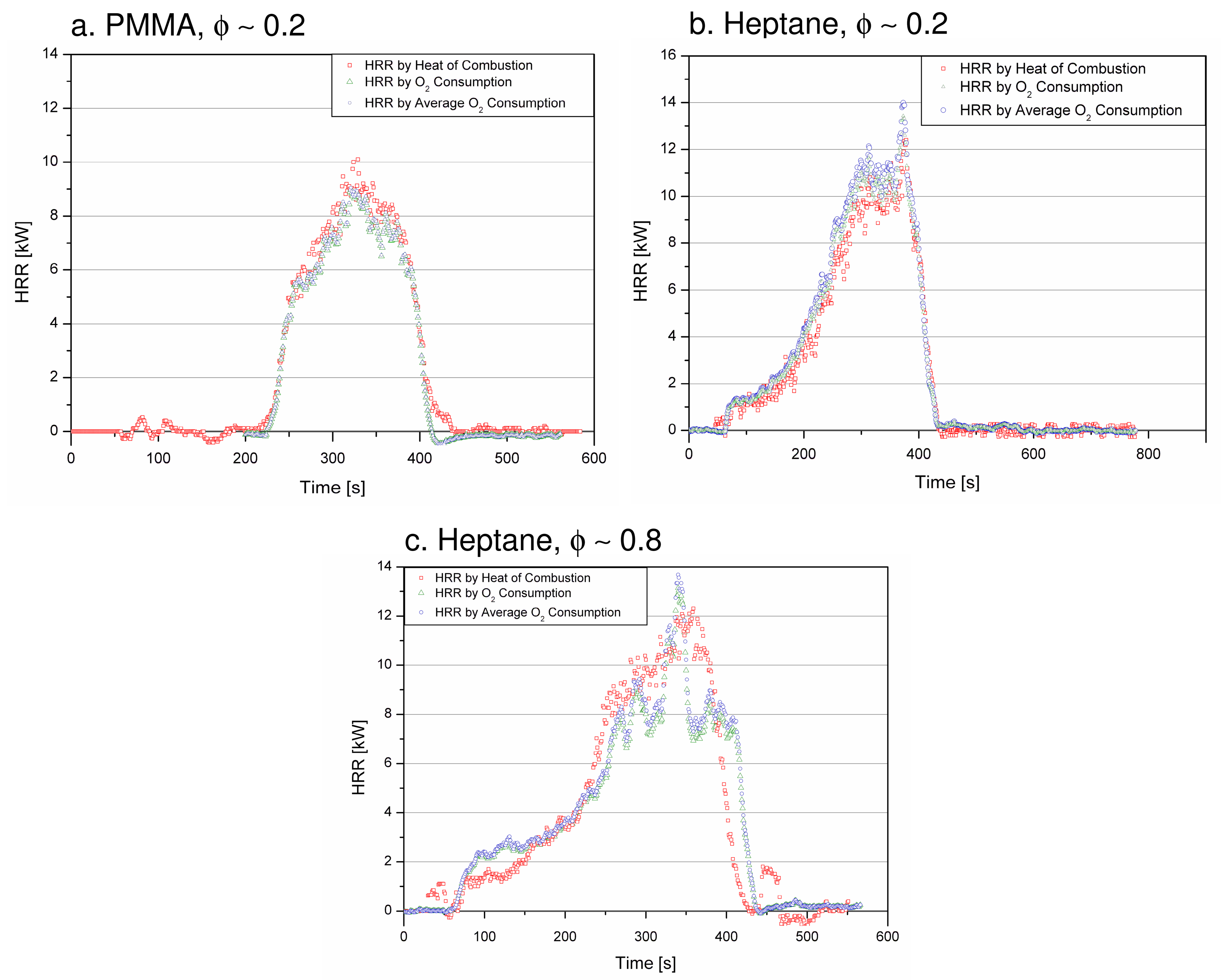

Figure. 2 : Heat Release Rate Calculations by using the Heat of Combustion of the materials, Oxygen Consumption Calorimetry with actual values for the calorimetric coefficients (E, α) and Oxygen Consumption Calorimetry with average values for E and α, for (a) PMMA, Incoming flow : 140 l.min^{-1}; (b) Heptane, Incoming flow : 140 l.min^{-1} and (c) Heptane (Under-ventilated fire), Incoming flow : 60 l.min^{-1}.

Future Work

– Series of tests will be carried out with 2 different smoke powders consisting in ternary mixtures containing starch and lactose as fuel components and potassium nitrate as an oxidizer in order to study their fire behaviour;

– Oxygen Consumption procedure will be applied to the 2 powders. The objective being to evaluate the calculation uncertainties to burning conditions where the oxidizer is also provided internally;

– Assessment of the ability of the FPA to study fast burning rate reactions.

References

1. ASTM E2058-03, "Standard Test Methods for Measurement of Synthetic Polymer Material Flammability using a Fire Propagation Apparatus", ASTM International, West Conshohocken, 2003.
2. Babrauskas, V. and Janssens, M. "Oxygen Consumption Calorimetry", *Heat Release in Fires*, pp31-59, Elsevier Applied Science, 1992.
3. Brohez, S. "Uncertainty analysis of Heat Release Rate measurement from oxygen consumption calorimetry", *Fire and Materials*, Vol. 29, pp 383-394, 2005.